Status and Trends in Fecal Coliform Contamination in Puget Sound Embayments

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Introduction

The Washington Department of Health (DOH) is mandated to protect the health of shellfish consumers from fecal contamination from humans and other warm-blooded animals. DOH monitors fecal coliform levels at over a hundred intertidal and subtidal commercial shellfish growing areas throughout Western Washington and classifies them according to their fitness for harvest.

The Department of Health participates in the Puget Sound Ambient Monitoring Program (PSAMP). An important goal of PSAMP is "to measure the success of programs implemented under the Puget Sound Water Quality Management Plan" (DOH 1995). DOH data from shellfish growing areas might address this and other PSAMP goals. This technical report addresses two questions: 1) whether fecal coliform levels have changed in PSAMP shellfish areas; and 2) whether trends are related to human activities.

Numerous watershed studies have shown how fecal pollution contaminates shellfish growing areas via several pathways (storm runoff, malfunctioning sewage treatment plants and failed individual onsite sewage systems, combined sewer overflows, faulty farm practices, boat waste, etc.). Considerable effort has been spent on pollution control in a number of Puget Sound watersheds. Remedial action has included (to greater or lesser degrees): 1) agricultural best management practices; 2) inspection and repair of failed individual on-site sewage systems; 3) low-cost loans for those with limited incomes to repair their on-site systems; 4) replacement or repair of sewage collection and treatment facilities; and 5) construction of stormwater treatment facilities.

In 1988 DOH selected nine growing areas for long-term PSAMP monitoring (Figure 1). Seven of the nine areas and their associated watersheds have been the focus of watershed planning and nonpoint source cleanup over the years. Two relatively undeveloped growing areas (Port Blakely and East Sound) serve as controls.

Methods

DOH uses a systematic random sampling strategy (ISSC 1995) to sample shellfish areas. Numerous sites within each growing area are regularly sampled. The sampling frequency depends on the DOH classification. "Approved" areas are sampled six times a year. "Conditionally Approved" areas are sampled monthly. Surface samples for fecal coliform analysis are collected at each site according to APHA (1984). Fecal coliform samples are packed on ice and sent to the W.R. Geidt Public Health Laboratory in Seattle. Analyses are run within 30 hours of collection. Fecal coliforms are analyzed with the multiple tube fermentation procedure using A-1 broth (Method 9221 E; APHA 1995). Surface measurements of salinity and temperature are also taken, in addition to tide and weather conditions.

Standards and Criteria

ISSC (1995) specifies a fecal coliform standard (based on systematic random sampling) as follows:

Criterion 1: Fecal colforms levels in samples shall not exceed a geomeric mean value of 14 organisms per 100ml.

Criterion 2: The estimated ninetieth percentile of fecal coliform samples shall not exceed 43 MPN per 100ml.

(Note: in order to comply with the growing area standard, both criteria must be met.)

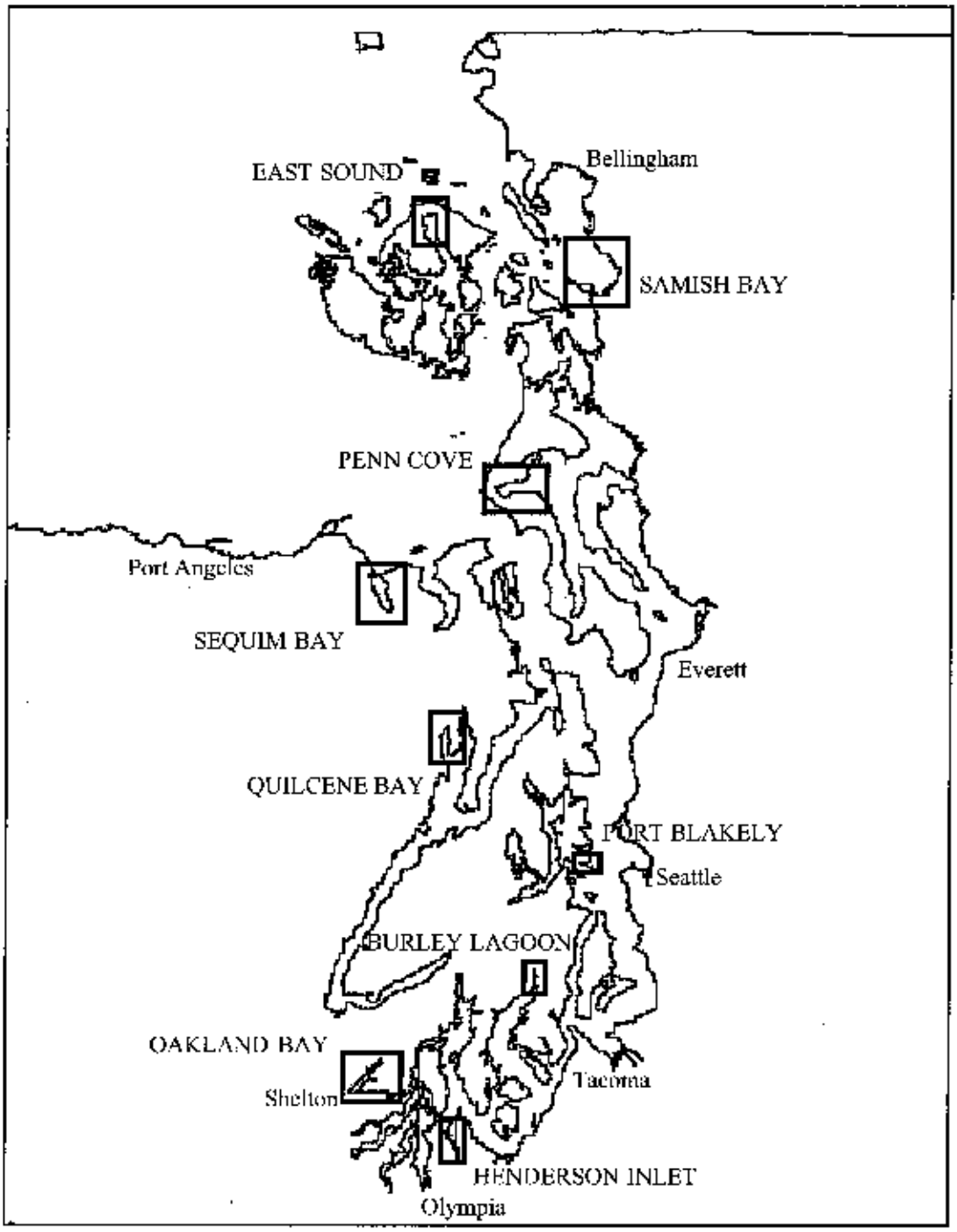

Figure 1. Nine shellfish growing areas selected for long-term monitoring for the Puget Sound Ambient Monitoring Program (PSAMP).

The NSSP protocol requires a minimum of 30 previous results to calculate the criteria. In other words, on any particular sampling date of interest, criteria are calculated from a minimum of 30 samples collected prior to that date. This means that in the case of "Conditionally Approved" areas (sampled once a month), nearly three years of data go into each calculation. In the case of "Approved" areas (sampled six times a year), nearly six years of data are included. These long periods effectively reduce variation inherent with fecal coliform data. Although ISSC (1995) requires a minimum of 30 prior results, the PSAMP analysis used a minimum based on full years with complete sets of seasons in order to minimize seasonal effects. For example, criteria for "Conditionally Approved" areas (sampled monthly) were calculated with a maximum of 36 samples to provide complete seasonal coverage.

Data Analysis

Criteria were calculated for sampling dates from the most recent date (end of calendar year 1997) back to a date beyond which the minimum sampling size could not be met. The criteria were then plotted versus time to detect trends. Trends in Criterion 2 (ninetieth percentiles) were tested with Spearman's *rho* and Kendall's *tau* (nonparametric statistical tests based on ranks). Criterion 2 was selected for trend testing because Criterion 2 typically changes more rapidly than Criterion 1 (geometric means). Status was determined on the percentage of dates within the two most recent calendar years (ending 1997) that fell into several compliance categories. As stated earlier, compliance required that both criteria be met.

Results

Henderson Inlet

Henderson Inlet was downgraded from "Approved" to "Conditionally Approved" or "Prohibited" between 1984 and 1985 (DOH 1997). Fecal coliform sources included failed onsite sewage systems, poor animal keeping on small farms, and stormwater generated in the City of Lacey. Since that time the Thurston County Health Department and Thurston Conservation District have facilitated on-site system repairs and best management practices for rural landowners. In 1991 the City of Lacey adopted standards for construction of stormwater facilities for all new developments. A number of facilities have been constructed as part of a regional stormwater management plan.

Twenty sites in Henderson Inlet have been sampled continuously since 1988. Results are summarized in Figure 2. Seventeen stations met the growing area standard on all dates during the most recent two-year interval (i.e., 100% compliance). Three sites (stations 3, 5, and 6) failed to meet the standard at least part of the time. These sites are located in the southern end of the estuary where watershed influence is high and dispersion through tidal exchange is minimal. Trend has been upward at 16 of 20 stations. One station shows a downward trend and three others have not changed significantly.

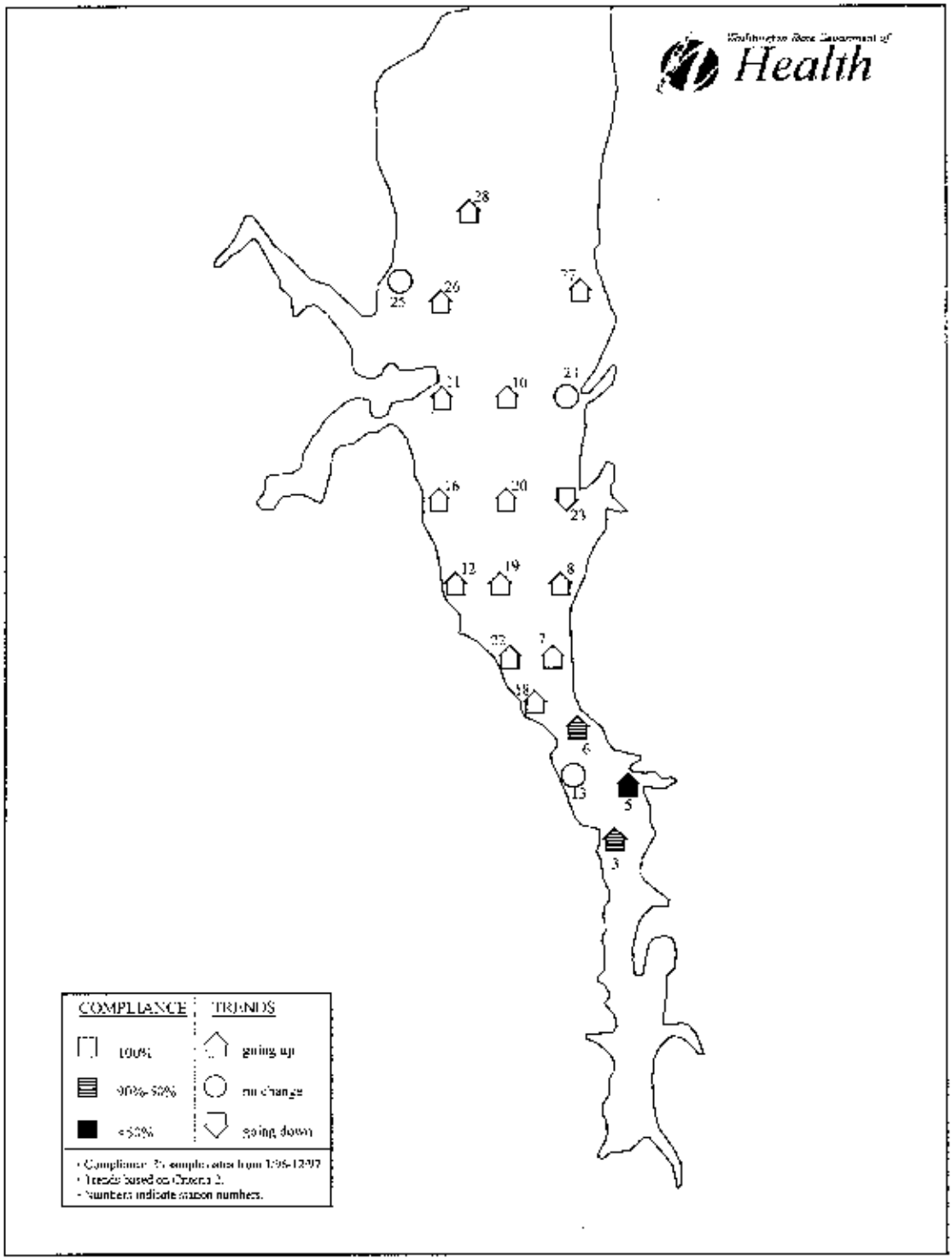

Figure 2. Fecal coliform trends and status in Henderson Inlet

Figure 3 shows plots of growing area criteria for three typical stations. Both criteria show steady upward trends. Note that the rate of change for Criterion 2 (ninetieth percentile) is greater than Criterion 1 (geometric mean). At Station 5, for example, Criterion 2 reached the allowable limit (43 MPN per 100ml) by late 1995. Thus Station 5 failed the growing area standard at that time. Criterion 1 did not reach its allowable limit (14 MPN per 100ml) until late 1997.

The graphs for Stations 11 and 26 are typical of most stations with increasing trends. Although trends are generally upward, the criteria remain within allowable limits. Thus, conditions in Henderson Inlet are generally good, considering the growing population and extent of development in the watershed. However, the slow but steady upward trend in the criteria suggest that control efforts will need to be intensified.

Figure 3. Fecal coliform trends in Henderson Inle

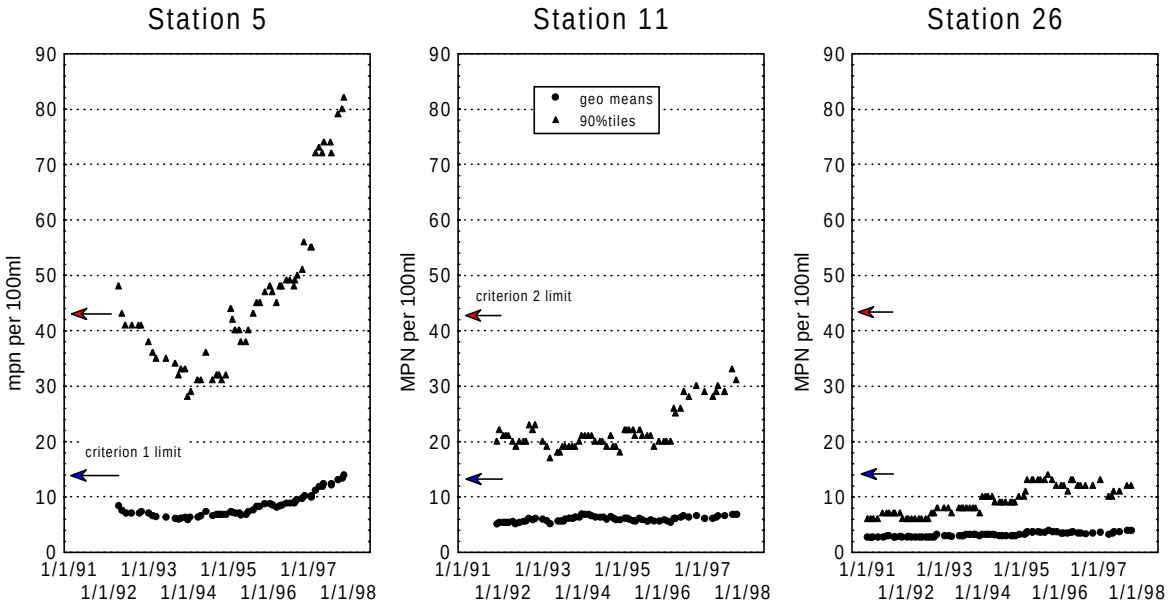

Figure 3. Fecal coliform trends in Henderson Inlet

Oakland Bay

Oakland Bay was downgraded to “Restricted” for shellfish harvest in 1987 (DOH 1997). The major fecal source was inflow and infiltration of stormwater into the sewer system during heavy rains. Sewage overflowed into Oakland Bay and also overloaded the sewage treament plant. During recent years, the city has renovated about half of the system and has expanded service to previously unsewered areas. Oakland Bay was upgraded to “Conditionally Approved” in 1989.

Figure 4 summarizes trends and status in Oakland Bay. All stations complied with the growing area in the most recent two years. Since 1991 Criterion 2 has decreased at nine of 10 sites since 1991, and remained unchanged at one site. The overall reduction may be explained, in part, by the partial renovation of the city's sewer system.

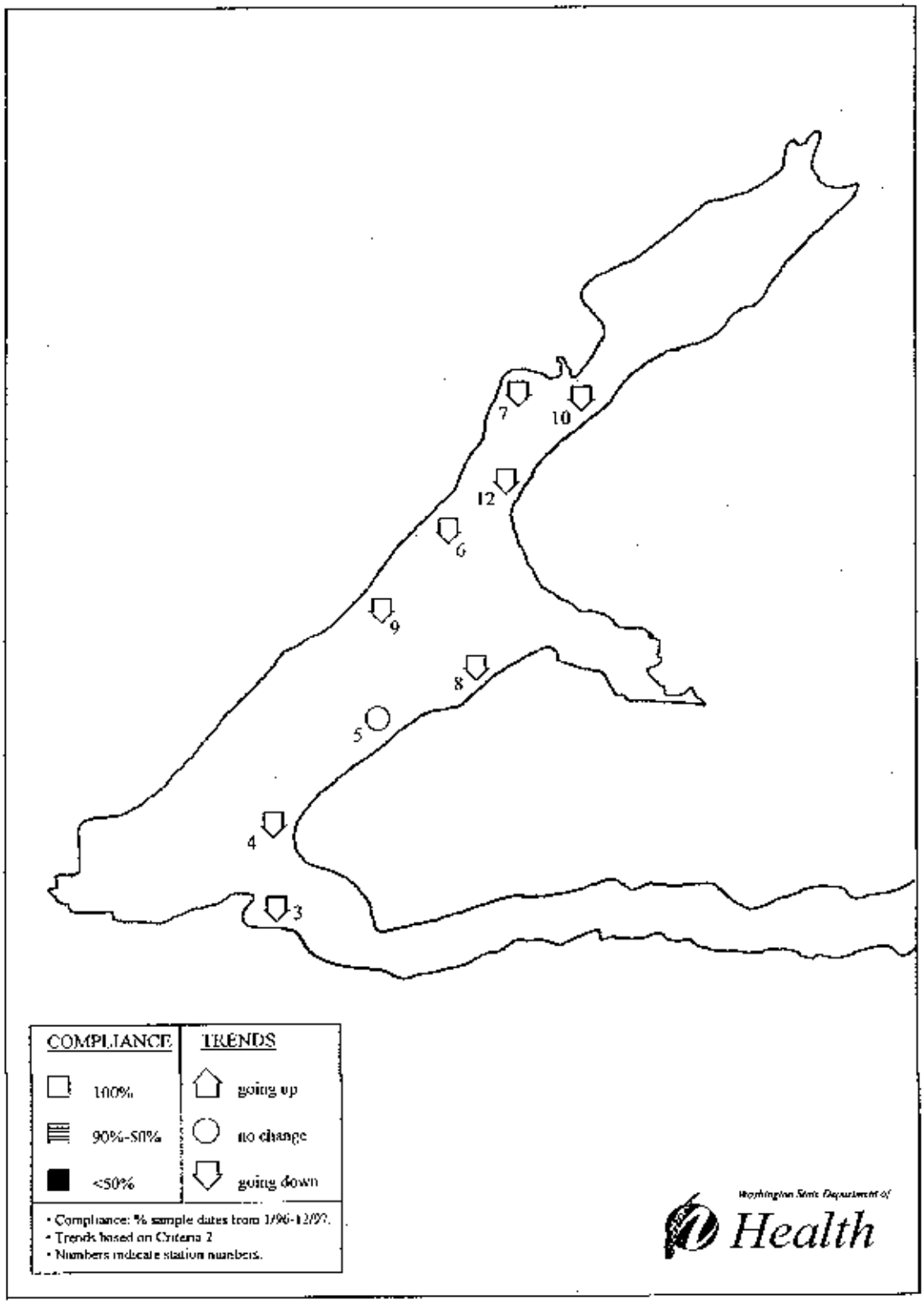

Figure 4. Fecal coliform trends and status in Oakland Bay

Figure 5 shows plots of criteria at three stations in Oakland Bay. The highest fecal coliform levels occurred at Station 3 near the discharge point of the Shelton Sewage Treatment Plant. Fecal coliform contamination has been markedly reduced in recent years. By late 1955, Criterion 2 values were reduced to a quarter of 1992 values. Since that time, Criterion 2 has remained at or slightly below the maximum allowable limit. The continuing renovation project should bring about even more improvement in coming years. However, these improvements must be balanced with the effect of rising population on the capacity of the sewage treatment plant.

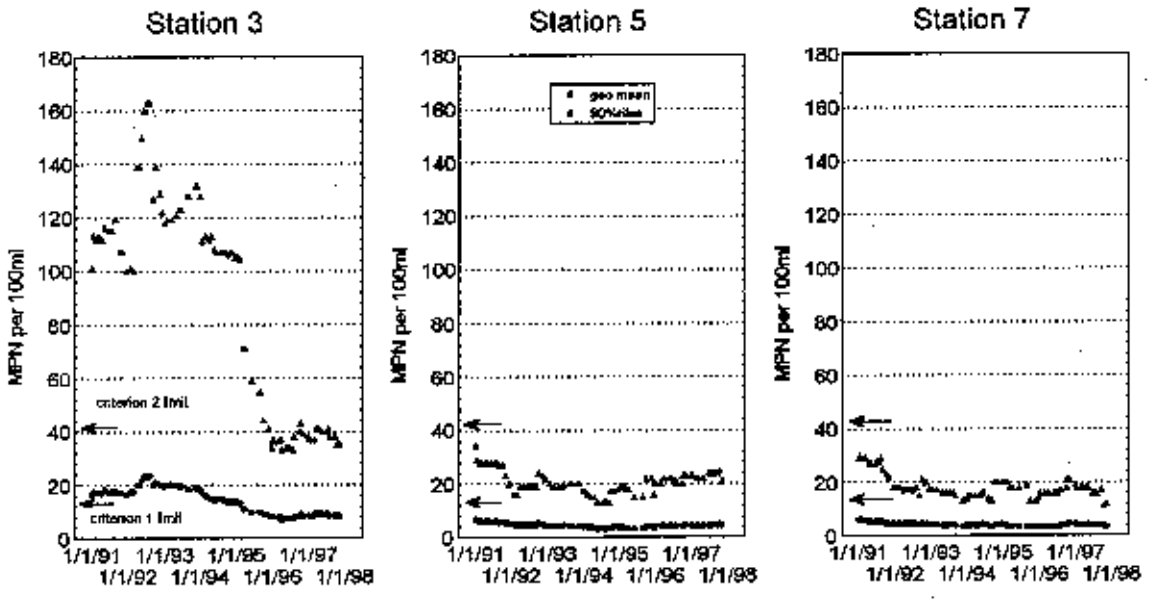

Figure 5. Fecal coliform trends in Oakland Bay

Burley Lagoon

Burley Lagoon was downgraded from “Approved” to “Restricted” in 1981 due to rural nonpoint pollution (DOH 1997). Since 1983, both Kitsap and Pierce county health agencies have inspected and facilitated repair of on-site sewage systems in the watershed. The Kitsap Conservation District has worked with rural landowners to implement best management practices. In addition, several large on-site sewage systems in Purdy have been either rebuilt or connected to a sewer line.

Figure 6 summarizes conditions in Burley Lagoon. Four of five sites complied with the shellfish standard from January 1996 through December 1997. A fifth site failed to meet the growing area standards on 29% of sampling dates during this period. Criterion 2 values increased at the three most southern sites since January 1995. Two other sites remained unchanged. The upward trend in fecal contamination is evidence of the need to continue to search for pollution sources in nearby uplands.

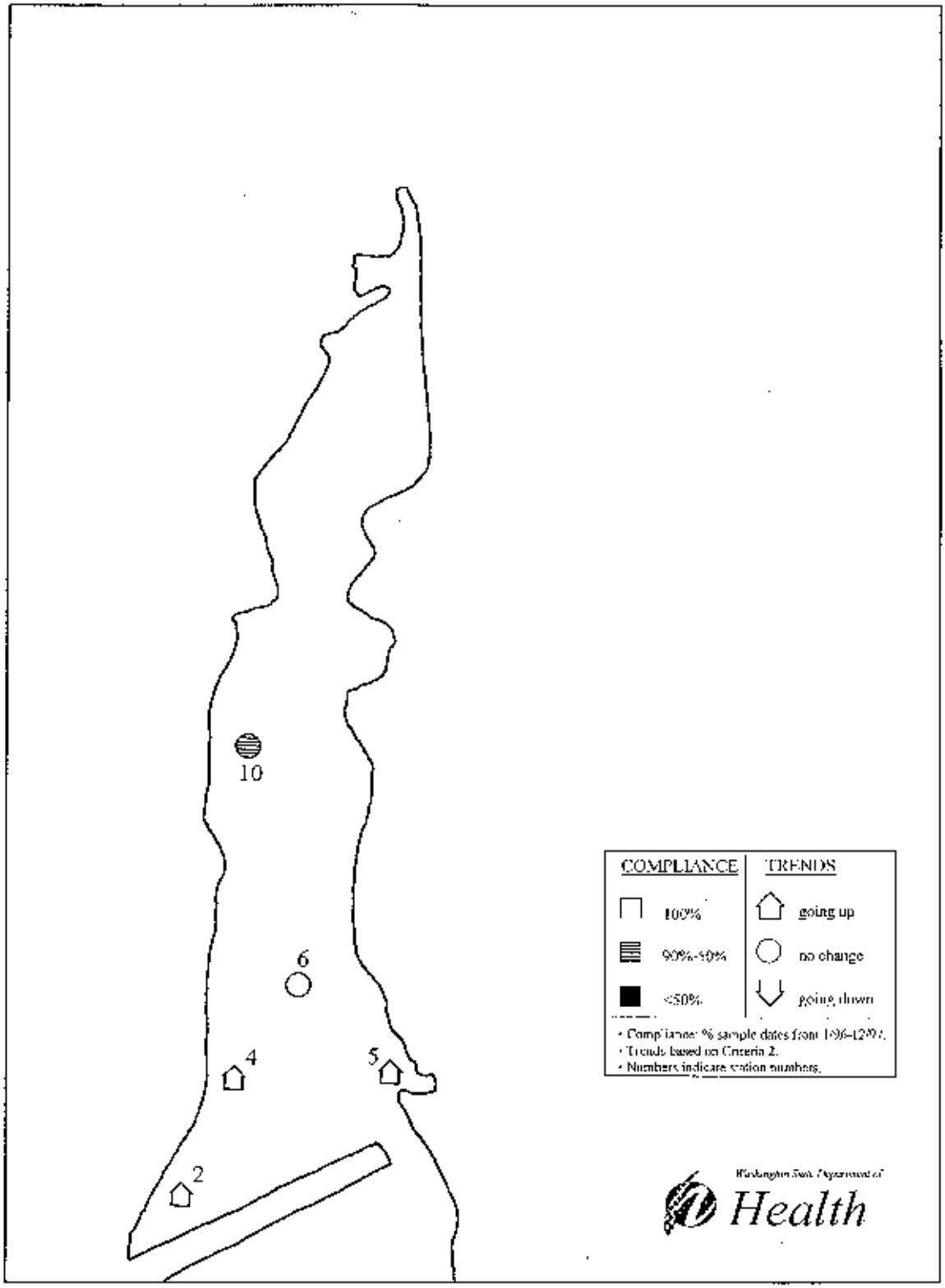

Figure 6. Fecal coliform trends and status in Burley Lagoon

Samish Bay

Samish Bay watershed in north Puget Sound differs somewhat from its three south Puget Sound counterparts (Henderson Inlet, Oakland Bay and Burley Lagoon). The Samish watershed is much larger. Farms are larger commercial operations. Pastures on the broad delta are diked from the Samish River and Bay. Pasture runoff is discharged through tide gates and pumps, rather than over land or through uncontrolled ditches. The pastures provide seasonal refuge for several species of migrating birds. Homes tend to be clustered into discreet small communities, rather than scattered over numerous small lots. Intensive residential development has been confined to the upper watershed.

In 1994 several growing areas in Samish Bay were downgraded from "Approved" to either "Restricted" or "Prohibited" (DOH 1996). The primary sources of contamination were failed on-site systems in Blanchard and discharge of raw sewage into Edison Slough from the Edison sewer system. Many failed on-site systems in Blanchard have been repaired. A new collection and treatment system with a ground discharge has just been completed in Edison. Remedial action has been driven primarily by citizen action in the two bayside communities.

Figure 7 summarizes status and trends in Samish Bay. Station 13 (near Edison Slough) failed the growing area standard on all sampling dates during the most recent two years. All other sites complied. Seven sites showed increasing trend in Criterion 2 (90th percentiles). These stations included Station 13, Station 10 in mid-bay, and stations 1–4 along the outer boundary of the sampling grid. Six sites showed decreasing trend, including three located in the northeast corner near Blanchard (Stations 6, 7, 8).

The improvement in the northeast end of Samish Bay may have been brought about by the repair of failed on-site sewage systems in Blanchard. Conditions at Station 13 have been stable recently. Criteria at this site should drop because discharge of raw sewage into Edison Slough has recently stopped.

The effect of agricultural discharge through the tide gates and pumps has not yet been thoroughly evaluated. However, conditions at sampling stations located closest to agricultural discharge points (Station 9 at mid-bay; and Stations 11 and 12 in the Southwest corner near Samish River) do not suggest major agricultural impact.

East Sound, Penn Cove, Sequim Bay, Quilcene Bay, and Port Blakely

Penn Cove and Sequim Bay are classified "Conditionally Approved." Penn Cove has been sampled since 1988. Sequim Bay has been sampled monthly since 1992. Most of Quilcene Bay, East Sound, and Port Blakely are classified "Approved," and have been sampled since 1992. Data from each of the five growing areas for all dates sampled were pooled and criteria calculated (Table 1).

Table 1. Growing area criteria in five PSAMP shellfish harvest areas.

PSAMP Area	Criterion 1 (geometric means)	Criterion 2 (ninetieth percentiles)
Sequim Bay	2.3	4.5
Penn Cove	2.5	6.5
Quilcene Bay	3.6	12.4
East Sound	3.2	9.1
Port Blakely	3.0	4.2

Table 1 suggests that fecal coliform levels in the five growing areas were generally very low. Both criteria were much lower than their respective maximum allowable limits. Each of the five growing areas has met the growing area standard. Trends were not calculated because, considering the low levels overall, trends would likely be meaningless.

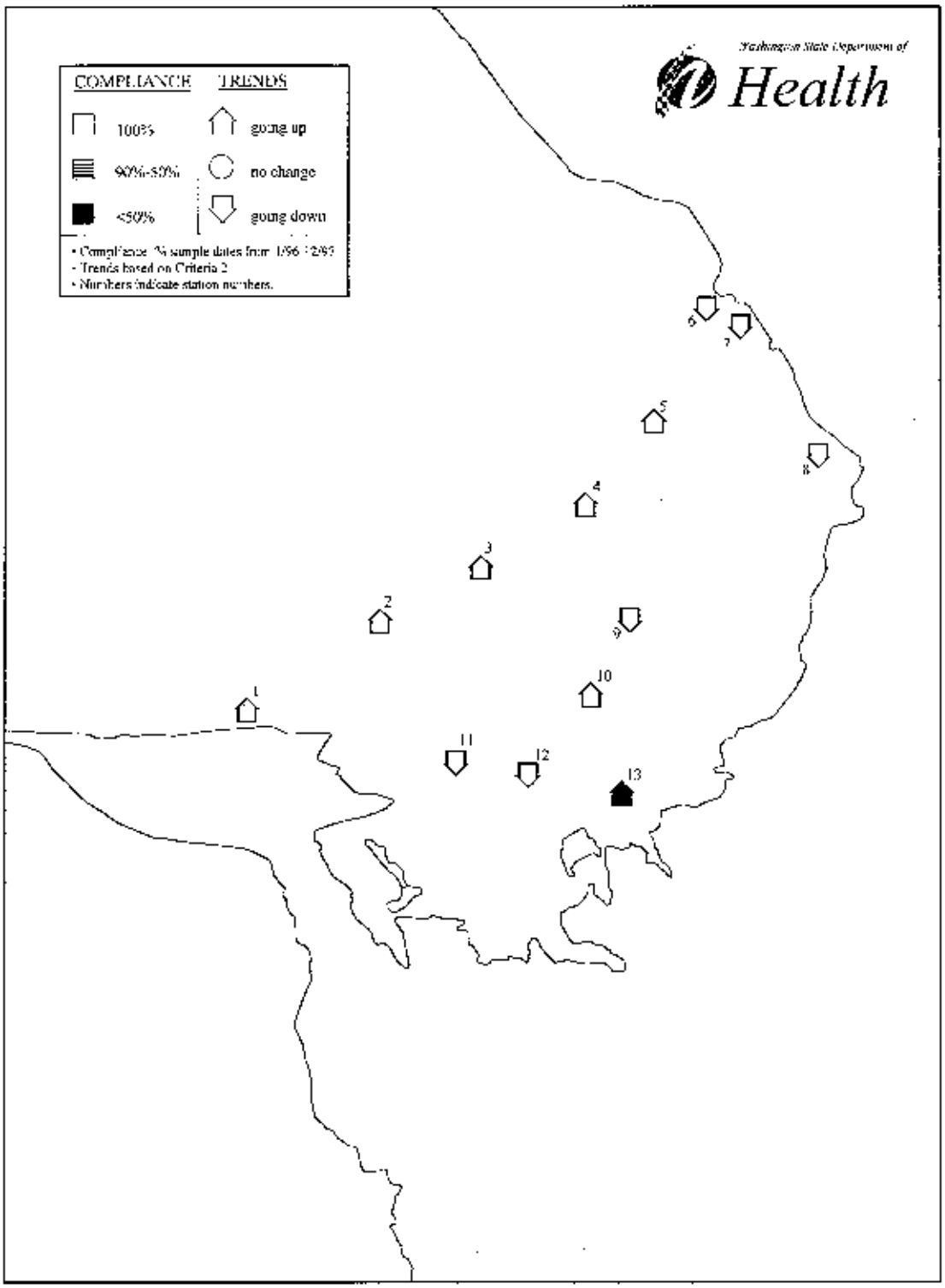

Figure 7. Fecal coliform trends and status for Samish Bay

Conclusions

Out of a total of 108 sampling sites in nine PSAMP growing areas, 103 sites met the growing area standard on all sampling dates during the last two years. Five sites failed to meet the standard on some dates. One site in each of Henderson Inlet and Samish Bay failed to comply on any date. The results suggest that serious fecal pollution tends to be highly localized. On the other hand, fecal coliform levels elsewhere in PSAMP areas are generally low in most places at most times. Trends in fecal coliform bacteria were determined in four PSAMP growing areas. Upward trends in criteria in Henderson Inlet and Burley Lagoon indicate the need to redouble the effort to locate and repair nonpoint sources of fecal pollution. Decreasing trends in criteria in Oakland Bay and parts of Samish bays are likely due to remedial action.

Fecal loading from urbanizing watersheds in Puget Sound will continue to threaten shellfish resources. The threat is exacerbated by potential failure of both existing treatment systems and new ones installed by increasing numbers of incoming residents. Nonpoint treatment systems must be perpetually monitored and maintained. This task must ultimately be borne by the rural homeowner. Government should fund programs to monitor rural treatment systems, educate and assist homeowners in their operation and maintenance, and assure their repair or replacement in case of failure.

Acknowledgements

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